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AN EVALUATION OF THE USEFULNESS OF
COLOR IN THE PATRIOT DISPLAY

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1.0 Introduction

The evaluation of the usefulness of color in the Patriot high altitude air defense weapon system display reported here is the third and final phase of research performed by the Army Research Institute (ARI) Fort Bliss Field Unit for the Directorate of Combat Developments (DCD), US Army Air Defense Artillery School (USAADASCH). Phases 1 and 2 of the research were (1) a survey of color research, and (2) the development of the experimental color display. These two phases were reported in the ARI Working Paper, "Preliminary Recommendations on the Use of Color in the Patriot Display" (Allender, 1986); Phase 3 consisted of an experiment run on the Patriot Tactical Operations Simulator (PTOS) comparing how trained Patriot operators performed using an experimental color display with how they performed using the existing monochrome display.

The entire research effort was prompted by two computer technology developments, one, a contributor to the problem, and the other, a possible solution. The problem is that, since computers are now faster and capable of displaying more information than ever before, the information processing limits of the human are being pushed and often exceeded. A case in point is the Patriot, which is described as the Army's first fully computerized weapon system (FM 44-15-1). The amount, kind, and timeliness of the information required by the Patriot is in direct response to the threat, which comprises more targets flying higher and faster and able to strike from farther out than before. In turn, the operator is presented with information on a rapidly changing, high density display, and is required to make complex decisions based on that information in a short period of time.

A possible solution to the problem of computer display clutter and information overload is color display technology. Since it has advanced to the point where literally millions of colors can be generated and displayed in high resolution, real time graphics, the potential for color to enhance information display is increased. Formerly, the use of color was limited to coding symbols or text in only three or four different colors. Now, with greater precision in color selection and improved display capabilities, the use of color can be extended to include highlighting critical information and reducing overall display clutter. This research effort, then, is an evaluation of the application of the new color technology to the problem of information display overload.

The organization of this report is as follows: Phases 1 and 2 of this effort, the survey of color research and the development of the experimental color display, are reviewed briefly in Section 2.0. The method and procedure for the evaluation are presented in Section 3.0 with emphasis on the performance measures and data collection techniques. The results of the experimental evaluation are discussed in Section 4.0, and the conclusions and recommendations are presented in Section 5.0.

2.0 Review of Phases 1 and 2

2.1 Survey of Color Research. Many different techniques have been shown by psychological research to improve the display of information. A number of them are already employed in the design of the Patriot display--symbol, shape and line coding, brightness coding, blink-rate coding, and formatting of tables. Color can also improve the display of information by coding categories of information, by highlighting critical information, and by reducing display clutter. However, just the addition of color to a display does not ensure an improvement. To ensure that color is used to advantage, at least three factors must be considered. (For a more detailed discussion of the use of color, see Allender, 1986.) For one, the display colors must be chosen carefully since the perception of a foreground object depends on the color of the surrounding area or background, particularly if the object is small. Poor foreground/background contrast makes an object hard to see. Also, certain foreground/background combinations can even change the perception of the color of the foreground object.

A second factor to be considered in using color is that there are tradeoffs and limitations. Color cannot code all available information: It cannot code both background and foreground information or different sections of a display with equal priority. Further, it cannot code more than one category of information for a given symbol or object. For example, it cannot be used effectively to code both the identity and the altitude of an aircraft. Also, the number of different color coded categories should be kept within limits: More than just a few color codes and the information processing capacity of the user is exceeded. Finally, although colors do not have standard meanings like words, color use should be consistent with any existing color-meaning associations. For example, in the military, green or blue are associated with friendly; yellow or white with unknown; and red with hostile.

A third factor to be considered in using color is the nature and extent of its effects on performance. Although color has been shown to enhance performance of some simple tasks such as checking 'go/no go' on system status, it does not necessarily enhance performance of more complex tasks such as landing an aircraft. Also, even if color does not directly affect performance, there is some evidence that it may reduce subjective estimates of workload, that is, how hard a task seems.

2.2 Development of the Experimental Color Display. With the above factors taken into consideration, an overall color scheme was developed for the Patriot display at the battery Engagement Control Station (ECS). (The battalion Information Coordination Central (ICC) display would be basically the same, but was not specifically developed for this experiment.) Before discussing the color display in more detail, it will be useful to describe the basic Patriot display. An illustration of the

display is shown in Figure 2.1 along with the switch-indicator panel, keyboard, special function keys, and joystick. The situation display comprises the largest area on the display and is where the symbol, shape, and line coding, the brightness coding, and the blink-rate coding are employed. It is a stylized map showing moving aircraft, or tracks, against a static background of objects such as search and track sectors, assets, safe passage corridors, weapons control volumes, and restricted and prohibited volumes. For a complete listing of the situation display objects and their coding, refer to Table 2.1. The alert message line and tabular display area are below the situation display and are where the formatting technique is employed. The alert message line (see Figure 2.2 for details) comprises a single line of text where priority messages are displayed in succession. The tabular display area comprises a rectangular area where tables of information are displayed one at a time. One such table is the Engaged Data Table (see Figure 2.3) which contains the To-Be-Engaged Queue (TBEQ) and the Engaged Queue. The monochrome version of the Patriot display as it was represented in this experiment is shown in Photograph 2.1.

The color version of the display is shown in Photograph 2.2. Color was essentially added to the monochrome display without changing the existing coding with two exceptions. One exception involved the use of the color-fill capability. Using that, areas and volumes were drawn as filled polygons, therefore eliminating the solid or dashed line coding. The other exception involved the elimination of blink coding. Due to system limitations on multiple blink rates, it was replaced with two types of track symbol modifiers that blinked at the same rate. Instead of a track blinking at 6 Hz when it was hooked, another smaller version of the track symbol (circle, "U", or diamond) blinked inside the track; and instead of a track blinking at 3 Hz when it was referenced by the alert message line, an "X" blinked inside the track.

A total of 14 different colors was used in the situation display including black for the background. The color scheme is consistent with military color-meaning associations: Objects associated with hostile information were represented in reddish or pinkish shades and those associated with friendly information in shades of blue. Other objects were represented in relatively neutral colors. In order to manage the potential color contrast problems, the background objects were of relatively low intensity, that is, not very bright, and fairly unsaturated. Foreground objects were of high intensity and highly saturated. In order to keep the number of color-coded categories within limits, objects with the same shape or line coding and objects grouped logically according to the similarity of information they provide were displayed in the same color. The number and letter designators for each object were also displayed in the same color as the object. For a complete listing of the situation display objects and their respective color coding, see also Table 2.1.

Figure 2.1. An illustration of the Patriot display. TM-9-1430-600-10-1, 1983.

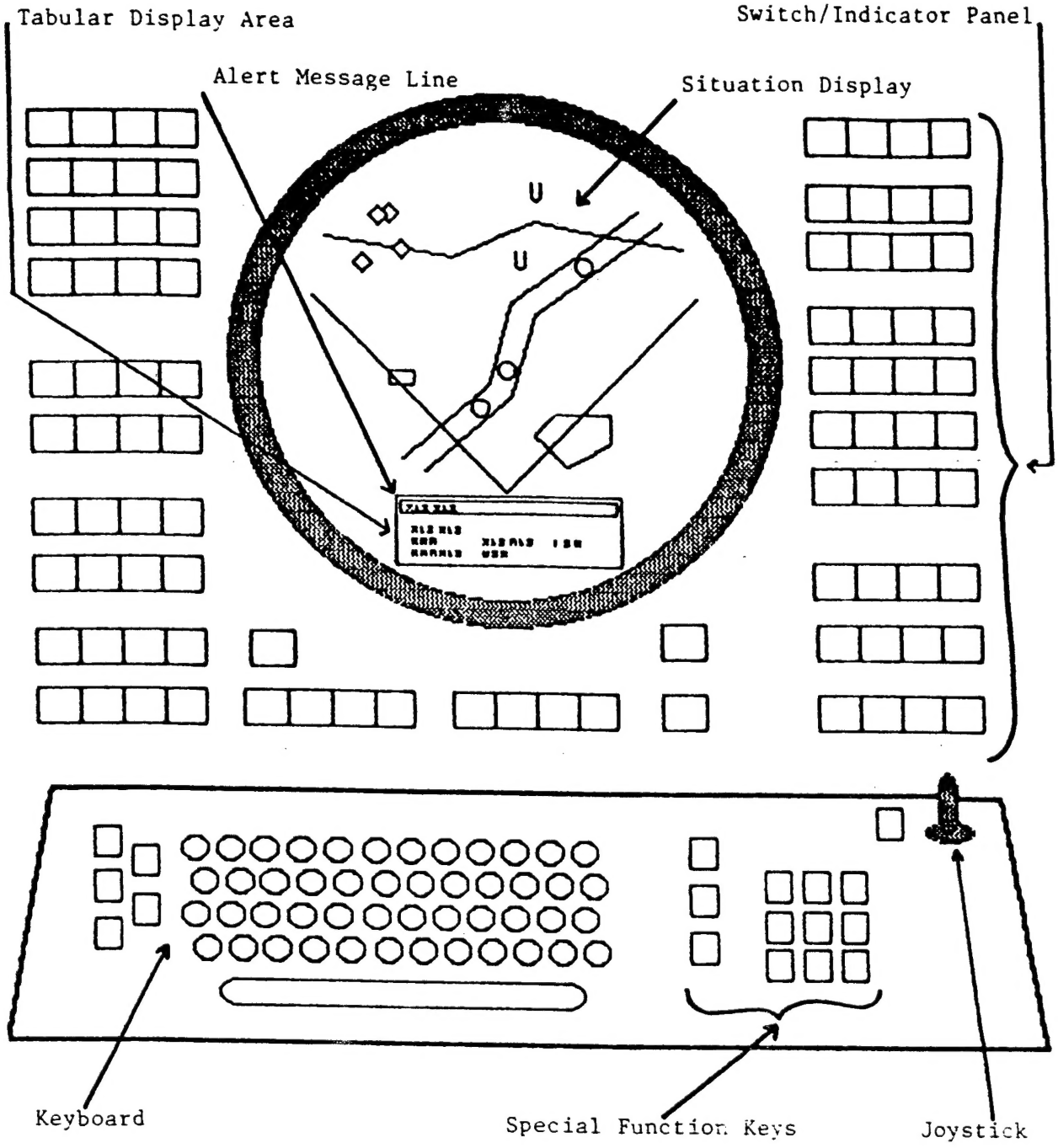
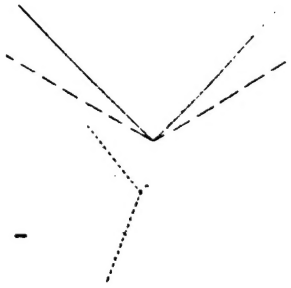


Table 2.1. Situation display objects and their respective shape, or line coding, blink coding, and experimental color coding.

Objects	Current Coding: Shape or Line	Current Coding: Blink	Color Coding
Search Sector		no	light aqua*
Track Sector		no	dark aqua*
Adjacent Sector Bounds		no	not displayed
Weapons Control Volumes -			
Hold		no	light orange*
Tight		no	light orange*
Free		no	light orange*
Restricted Volume		no	light pink*
Prohibited Volume		no	light pink*
Hostile Origin		no	not displayed
Friendly Origin		no	not displayed
Safe Passage Corridor		no	light blue*
Defended Area/Point		no	medium blue*
FEBA		no	white
Masked Terrain		no	bright orange
Range Rings		no	dark purple
Fire Platoon Flag		no	yellow-green
Battalion Flag		no	yellow-green
Communications Relay Group		no	yellow-green

Note. The shape or line coding is not to scale. 'Yes' under the Blink Coding column indicates that the object blinks at 6 Hz when the track is hooked and at 3 Hz when the track is referenced by the Alert Message Line. Color codes marked with an asterisk mean that the objects were solidly colored, that is, color-fill was used. Currently and in the experimental color display, the background is black.

Table 2.1 con't.

Objects	Current Coding: Shape or Line	Current Coding: Blink	Color Coding
North Symbol	N	no	white
Friendly Track (Single, Multiple)		yes	dark blue
Unknown Track (Single, Multiple)		yes	yellow
Hostile Track (Single, Multiple)		yes	red
To-be-engaged Modifier		yes	same color as track being modified, for example, for hostile track modifiers were red
Engaged Modifier		yes	
Kill-assessed Modifier	#	yes	
Engage-hold Modifier	H	yes	
LNIP (Launch-now-intercept point)		no	
PIP (predicted intercept point)		no	
Altitude/Threat Information	093	yes	
Track Number	001	yes	
Missile		no	

Figure 2.2. Alert Message Line displaying the message that track number 002 is a priority engagement and the word "more" indicating that additional messages are waiting to be displayed when this one is cleared.

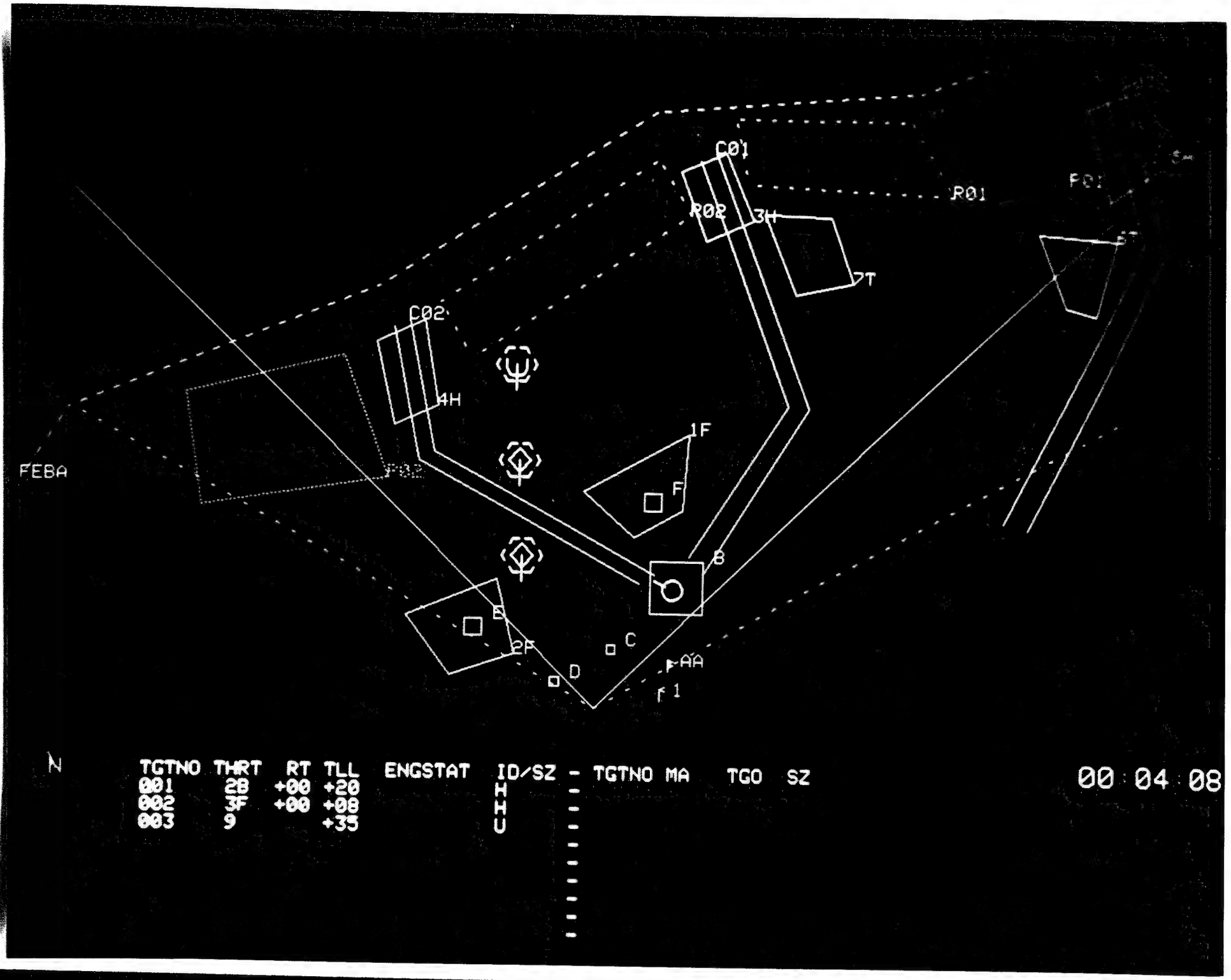
Figure 2.3. The Engaged Data Table with entries on the TBEQ (left six columns). No entries are shown on the Engaged Queue (right four columns). TGTNO = target number; THRT = ATC value; RT = release time; TLL = time to last launch; ENGSTAT = engaged status; ID = identification; SZ = size; MA = missile away; and TGO = time to go until intercept.

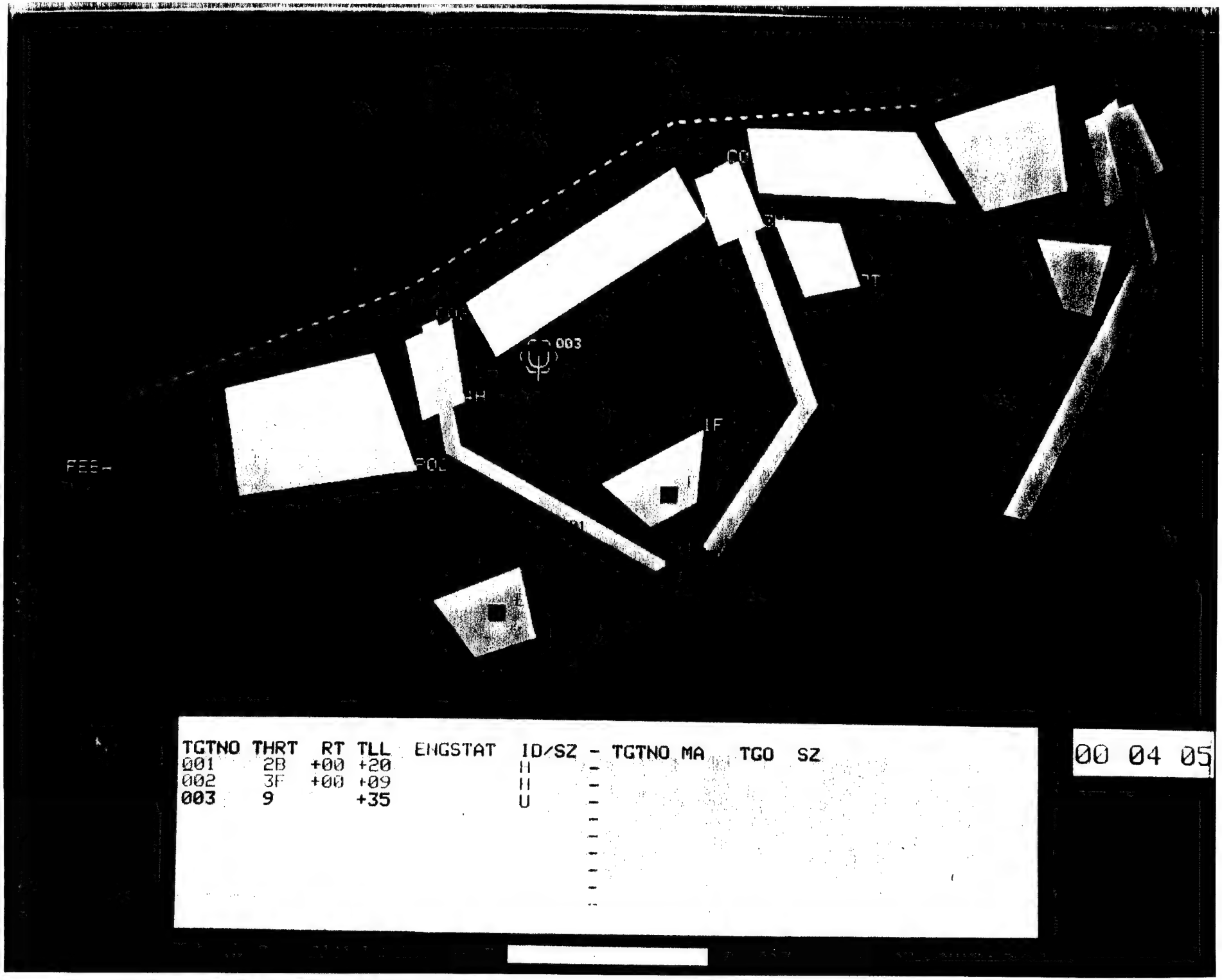
TGTNO	THRT	RT	TLL	ENGSTAT	ID/SZ	_TGTNO	MA	TGO	SZ
001	1	10	30		H				
002	1	0	20		H/2				
003	9	15	99		H				

The alert message line was not specifically color-coded. For this area, the background was a light gray and the text was black. This color combination allowed for sufficient contrast and yet was relatively easy on the eyes. Another reason for choosing these colors was so that the contrast was in the same direction as the situation display: dark, saturated foreground text on a light background. Just two different colors were used in this area, black and light gray.

Many different tables of information can be displayed in the tabular display area but color coding was implemented on only one table, the Engaged Data Table. Otherwise, for all tables, the background and foreground text were the same colors as for the alert message line, light gray and black, respectively. On the Engaged Data Table, TBEQ entries were color coded to highlight critical information. When Release Time (RT) was equal to zero, the entry appeared in red. When RT was greater than zero, but Asset Threat Category (ATC) was equal to one, the entry appeared in yellow. (In the scenarios used, however, this situation never occurred.) All other entries appeared in the standard text color, black. Thus, in this area, a total of four different colors was used: black, light gray, red, and yellow.

On the following page, Photograph 2.1. Monochrome version of the Patriot display.


C01
R01
R02
3H
7T
C02
4H
1F
F
FEBA
B
E
2F
C
D
AA
1
N
TGTNO THRT RT TLL ENGSTAT ID/SZ - TGTNO MA TGO SZ
001 2B +00 +20 H
002 3F +00 +08 H
003 9 +35 U
00 04 08


003
TGTNO THRT RT TLL ENGSTAT ID/SZ - TGTNO MA TGO SZ
001 2B +00 +20 H -
002 3F +00 +09 H -
003 9 +35 U -
00 04 05

On the preceding page, Photograph 2.2. Color version of the Patriot display. Due to the difficulty in photographing raster scan displays, the colors in the photograph are degraded somewhat. They were actually substantially brighter.

3.0 Evaluation Method and Procedure

The evaluation method and procedure will be discussed in five sections: 3.1 Test Operators, 3.2 Equipment, 3.3 Scenarios, 3.4 Performance Measures, and 3.5 Testing. Serving as an introduction, an overview of the method and procedure will be given first.

The performance of operators, both officers and enlisted personnel, in the Weapons Controller position at the ECS was investigated. The Weapons Controller is responsible for carrying out engagement decisions, that is, decisions to fire on a hostile track. The PTOS was operated in independent and autonomous modes so that operators were on their own in deciding what to engage and when. The test operators were given twelve different scenarios with three levels of track load and two levels of background load (e.g., the number of volumes) under the two display conditions, monochrome and color. They were instructed to defend the assets to the best of their abilities, to engage tracks in a timely fashion, and to conserve missile resources. Their performance was assessed through mission level Summary Performance Measures (SPMs); more specific Task Performance Measures (TPMs); and the Subjective Workload Assessment Technique (SWAT). Ratings of eye comfort, viewing comfort, image appearance, and overall ease of viewing, display preference, and general comments were also solicited.

3.1 Test Operators. Trained Patriot operators from the 1st Patriot Battalion/43rd Brigade and from the Identify Friend, Foe, or Neutral/Joint Task Force at Fort Bliss, Texas participated in the study. The criteria for being trained was that they had completed both the individual school training and the collective field training. Twenty-four operators, 12 officers (14Es) and 12 enlisted personnel (24Ts) were tested. Although the 24T is usually designated the Weapons Controller, the 14E is cross-trained as the Weapons Controller and, therefore, is suitably familiar with the task. An additional seven operators were tested as a part of preliminary pilot testing.

3.2 Equipment. A Raster Technologies Model One/80 was the display equipment used for the study. Its key capabilities are real time interactive graphics, 1280 x 1024 pixel (picture element) display resolution, multiple display windows, polygon fill, and a palette of 16.7 million colors. Although 16.7 million different colors can be generated, only a subset of that number could be displayed simultaneously given the other display requirements. The experimental display configuration was capable

of displaying a maximum of 27 different colors and of that, a total of only 16 different colors was actually used. So instead of a simultaneous display capability, the 16.7 million colors provided the needed flexibility to select precise shades.

The color display system was driven by the pre-deployment build PTOS scenario software residing in the host computer, the Gould S.E.L. 32.77 under operating systems 1.5B and 2.2. To complete the system, a keyboard and joystick were used as input devices and specially constructed button boxes were used as the switch-indicator panels.

3.3 Scenarios. Scenario development was accomplished using a menu-driven scenario development procedure, the PTOS Scenario Preprocessor. Scenarios are created by specifying the background information: the location of the assets, fire platoon, battalion, forward edge of the battle area (FEBA), weapons control volumes, hostile identification volumes, safe passage corridors, and origin volumes; and the track or foreground information: speed, altitude, and intended target. A base scenario was built based on realistic tactical information provided by Army subject matter experts in an existing scenario, Acceptance Test Program 5 (ATP5). The training and test scenario were subsets of the base scenario. Three levels of hostile track load (see Table 3.3.1) and two levels of background load (see Table 3.3.2) were used. Most scenarios had some hostile tracks that were not targeted against an asset, for example, tracks that flew into the area of coverage but then turned and left the area. Track entries were spaced such that activity was spread throughout the six minute duration of the scenario.

3.4 Performance Measures. Multiple aspects of performance were assessed in this experiment because, as pointed out in the survey of color research (Section 2.1), the effects of color may not be seen at all levels of performance. In the following sections, each of the different measures will be discussed.

Table 3.3.1. Track loads and characteristics.

	Hostiles			Friendlies
	Total	Targeted Against Assets	Not Targeted Against Assets	
Track Load				
Low	3	2 - 3	0 - 1	2 - 4
Moderate	6	4 - 5	1 - 2	2 - 4
High	12	7 - 10	2 - 6	4 - 6

Table 3.3.2. Background load levels.

	Background Load	
	Simple	Complex
Background Display Objects		
Assets	6	6
Safe Passage Corridor	1	3
Weapons Control Volume - Hold	1	3
Weapons Control Volume - Tight	1	2
Weapons Control Volume - Free	1	2
Prohibited Volume	1	2
Restricted Volume	1	2
Masked Terrain	0	2

Summary Performance Measures (SPMs). The SPMs, based on earlier ARI work (Hawley, Howard, & Martellaro, 1982), are aggregate measures designed to capture overall system performance--man and machine--at the mission level. Mission level performance is measured in relation to bottom-line or long-term goals. The SPMs are Probability of Kill (PK), Resource Conservation (RC), and Defense of Assets (DOA). 1

PK is defined as the ratio of the number of tracks killed to the number launched on for a given scenario. The formula is:

$$PK = tk / tlo$$

where tk = tracks killed and
tlo = tracks launched on.

Note that PK is different from attrition, which is the ratio of tracks killed to those available.

RC is the ratio of missiles wasted to those launched, corrected for system failures for a given scenario. It is scaled from 0, all missiles wasted, to 100, no missiles wasted. The formula is:

$$RC = [1-(nmw / nml - nmf)] * 100$$

where nmw = number of missiles wasted,
nml = number of missiles launched, and
nmf = number of missiles failed.

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1 The SPM Air Space Defense as developed by Hawley et al. (1982) was not included because it proved to be insensitive over the range of values seen here. Instead, PK was calculated as an indication of how well the air space was defended.

DOA is the ratio of assets, weighted by priority, that were successfully defended to those that were scripted for penetration. The number actually scripted for penetration can be smaller than the number of assets the system determined were being threatened throughout a scenario. DOA is scaled so that a score of 0 means all assets were penetrated and 100 means no assets were penetrated. The formula for calculating DOA is:

$$DOA = 1 - \frac{\sum\{(10 - ap) * p\}}{\sum\{(10 - ap) * s\}} * 100$$

where n = the number of assets in the scenario;
m = the number of tracks in the scenario;
ap = the priority value of the asset;
p = 1 if the asset is penetrated, and
0 if the asset is not penetrated;,
s = 1 if the asset is scripted for penetration, and
0 if the asset is not scripted for penetration.

For the purposes of the DOA score, the asset priority values which range from 9, the lowest, to 1, the highest, are subtracted from 10 so that a high priority asset will have a high weight and a low priority asset will have a low weight.

The information required to calculate the SPMs was obtained from the Performance Assessment Capability (PAC), a data reduction capability implemented on the PTOS. Information was collected at the conclusion of each scenario: the number of engagements; the number of tracks launched on and killed; the number of missiles launched, wasted, and failed; and the number of assets penetrated. These data were transferred by tape to the ARI VAX 11/730 computer for further reduction and analysis.

Task Performance Measures (TPMs). The TPMs measure performance in relation to immediate, relatively short-term goals. They provide information about two aspects of operator performance: the timeliness of engagements, and the different activities performed throughout the scenario.

Timeliness of engagements was calculated in two ways: as the number of seconds a given track was engaged before or after RT = 0, and as the displayed value of TLL at engagement. These two measures can be thought of as the two ends of the engagement window. RT is the first opportunity for engagement of a given track, and TLL is the last opportunity before it penetrates an asset or leaves the area of coverage. The data for the calculations were drawn from the PAC data collected on each track at one-second time hacks: identification (unknown, friend or hostile), object modifier (no status, to-be-engaged, engaged, under kill-assessment), RT, and TLL. The data were reduced and analyzed on the VAX 11/730.

In calculating engagement time in relation to RT, if an engagement occurred prior to RT = 0, the time was considered negative; and if an engagement occurred after RT = 0, the time was considered positive. The time for each engagement was included in the calculation even if it was a repeat engagement or an engagement that later failed. The percent of the total engagements that were early was also figured.

The calculation of mean displayed TLL value was straightforward although it should be noted that it does not have a one-to-one correspondence with clock time. TLL counts down from 99 seconds to 0 seconds, but may jump from 99 to some intermediate number and then count down sequentially from there. Also, TLL may count down more than once during a scenario as a track is paired against successive assets.

Information about the different activities performed was obtained by first generating a list of possible operator activities from TM 9-1430-600-10-1 (1983) and from Outline Training Plan for Patriot ECS Console Operators (Brett & Chapman, 1983). The activities were then categorized based on their frequency of occurrence during the performance of the Weapons Controller task. The resulting 17 categories of activities are listed in Table 3.4.1. Data on the activities were collected using an Apple IIe micro-computer. The experimenter observed the operator during the test and "shadowed" the operator's actions. In other words, when the operator began an activity, the experimenter pressed a corresponding, coded key on the Apple, each of the 17 activities having been assigned to a different key. For each key-press, the code for the key and the time were recorded at one-second time hacks. Thus, the time spent on each

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Table 3.4.1. List of activities possible to be performed by Patriot Weapons Controllers at the ECS.

1. Select and inspect Track Amplification Data Table
2. Select and inspect Engagement Data Table
3. Select and inspect other tables
4. Select/deselect displayed track data
5. Drop track from display
6. Change display size or offset display
7. Engage
8. Request hold fire, cease fire, or engage hold
9. Select method of fire
10. Perform IFF (Identify Friend or Foe) activity
11. Perform other identification activity
12. Acknowledge and inspect alert
13. Cursor hook a track
14. Number (num) hook a track
15. Sequence hook track from the TBEQ
16. Cancel a hook on a track
17. Otherwise monitor the display

---

instance of a given activity is calculated by subtracting the start time of the activity from the start time of the next activity. The number of instances and the mean time per instance of each of the activities were calculated for each scenario. The raw data were recorded on floppy diskettes and transferred to the VAX 11/730 where they were reduced and analyzed.

Subjective Workload Assessment. The Subjective Workload Assessment Technique (SWAT) (Reid, Shingledecker & Eggemeier, 1981) used in this experiment was developed by the USAF Aerospace Medical Research Laboratory at Wright-Patterson Air Force Base. It provides an overall subjective assessment of workload based on assessments across three dimensions: time load, mental effort load, and psychological stress load, each of which can vary according to three levels of load. In addition to considering the multidimensionality of workload, this technique takes into consideration individual differences in subjective assessment.

The procedure for obtaining the subjective workload ratings has three main steps. First, each operator rank orders the 27 combinations of the three levels of the three dimensions by sorting a deck of 27 cards. (See Appendix A for an example of one of the 27 cards.) The rank orders are then subjected to computer analysis (c.f., Nygren, 1982) to arrive at a single scale, 0, low workload, to 100, high workload, for the group. (The scale arrived at here is included in Appendix A.) The second step is to obtain workload ratings, 1, 2, or 3, for each of the three dimensions, on the task of interest. In this experiment, ratings were obtained from each operator after each scenario. (The SWAT rating scales used in this experiment are shown in Appendix A.) The third step is to reduce those ratings to a single number on the basis of the derived scale. These scores are then subjected to further analysis.

Subjective Opinions. Subjective ratings or opinions were solicited from the operators on several factors important for comparing the monochrome and color displays. Ratings were obtained on two dimensions of eye comfort, two dimensions of viewing comfort, five dimensions of image appearance, and overall display ease of viewing, based on dimensions identified in work published by Christensen, Baggen, and Snyder (1985). (The ratings were made on the rating scales shown in Appendix B.) A display preference and general comments about the colors and suggestions for changes were also obtained.

3.5 Testing. Each test operator attended two testing sessions, a small group session with up to four test operators and an individual session. The first stage of SWAT, the introduction and card sorting, and display and equipment familiarization were accomplished in the small group sessions. It was important to ensure display and equipment familiarization since there are some configural differences between the color display system and the tactical Patriot system.

Testing with the display was conducted in the individual sessions. First, each operator worked through two practice scenarios, each lasting ten minutes on the scenario clock, one in monochrome and one in color. Half the operators practiced with the displays ordered monochrome-color; half with the displays ordered color-monochrome. During the practice, the operator was permitted to ask questions of the experimenter.

Next, each operator worked through the 12 test scenarios, each lasting six minutes on the scenario clock. All operators saw the 12 scenarios in the same order, which was random with the control that the two test halves were balanced with respect to track load and background load. All the operators worked through six scenarios in monochrome and six in color. Half the operators were tested with the displays ordered monochrome-color; half with the displays ordered color-monochrome.

Assignment of operators to the training and testing orders was controlled such that equal numbers of officers and of enlisted personnel were in each experimental condition. Table 3.5.1 shows the resulting assignments.

The SWAT ratings were made after each scenario. The ratings of eye comfort, viewing comfort, image appearance, and overall ease of viewing were made after the first six scenarios (i.e., after all of one display type), and again after the second six (i.e., after all of the other display type). The choice of display preference and the comments were made at the end of the entire testing session.

Table 3.5.1. Number of test operators, officers and enlisted in each of the testing order and training order conditions.

	Testing Order	
	Mono-Color	Color-Mono
Training Order		
Mono-Color	3 14E	3 14E
	3 24T	3 24T
Color-Mono	3 14E	3 14E
	3 24T	3 24T

4.0 Results and Discussion of the Evaluation

Data analysis for all of the measures proceeded in two main steps. First, the measures were calculated from the raw data. Then, the measures were subjected to a repeated measures analysis of variance. Because of the large number of experimental variables in the analysis model (see Table 4.1 for a complete listing), a discussion of all of the individual effects and interactions is beyond the scope of this report. Therefore, the

Table 4.1. Experimental variables.

Personnel:	Officer	Enlisted	
Training Order:	Mono-Color	Color-Mono	
Testing Order:	Mono-Color	Color-Mono	
Display:	Monochrome	Color	
Track Load:	Low	Moderate	High
Background Load:	Simple	Complex	

emphasis throughout this section will be on the overall pattern of results as they pertain to the evaluation of the usefulness of color in the Patriot display. A more complete discussion of the results will appear in an ARI technical report.

The predominant effect across the measures, the effect of the order in which the displays were presented to the operators, warrants further comment before proceeding. Two reasons underlie the effect. One is the differential degrees of familiarity with the two display types: The operators' pre-experiment experience was entirely with the Patriot monochrome display. Thus, at the beginning of the testing session, even though all the operators had just practiced on both the monochrome display and the color display, the monochrome display was highly familiar and the color display was only somewhat familiar. The second reason is that, since some aspects of the simulation itself were different from the actual Patriot (e.g., the switch-indicator response time, etc.), two new things were actually being presented to the operators in this experiment--the simulation system and the color display. Operators in the Mono-Color test order were able to gain familiarity and expertise with the simulation system before being tested on the color display, whereas the operators in the Color-Mono test order were tested on the color display at the same time they were gaining familiarity and expertise with the simulation system. So, the effects of testing order must be considered in order to properly understand the effects of the color display.

In reading this section, several other things should be kept in mind. For one, most of the effects reported here are small and should be interpreted as such for application to a practical situation. Also, although the operators are trained, their console experience was not necessarily recent and so their level of performance probably was lower than would be expected otherwise. Finally, with this particular system configuration, real time was degraded somewhat with increasing track loads. Thus, the track load manipulation must be interpreted cautiously.

The results for each type of measure will be reported in the separate subsections which follow. For comparison, the system measures will be reported where applicable. They were computed from data obtained when running the system in automatic mode with no operator intervention.

4.1 Summary Performance Measures. [2] To preview the results found with the SPMs: Overall, operator performance was below that of system performance. Considering the operator PK, RC and DOA scores together, the improvement in PK over time was at the expense of a lower RC score, that is, more aircraft were killed but more missiles were wasted. Moreover, increased PK did not result in better DOA. Apparently the tracks were killed after the assets were penetrated. Across all three SPMs, performance with the color display was slightly lower than that with the monochrome display; however, this difference was attenuated somewhat by the second test half for PK and DOA, presumably due to the operators simply gaining experience with the color display and overcoming the poor performance with the color display in the first test half. This "catching up" done by the operators who had the Color-Mono test order was evidenced as improvement in PK and no further decrement in RC. DOA showed a different pattern: Performance was initially higher with the color display but decreased more over time.

Probability of Kill. The mean number of tracks engaged for each scenario is shown in Table 4.1.1 along with the minimum and maximum number of tracks engaged. The number of tracks engaged varied across scenarios because of the three levels of the track load variable. Note, too, that the number of tracks engaged varied within a given scenario. This occurred because sometimes low threat tracks were engaged unnecessarily and other times high threat tracks were not engaged when they should have been.

The mean operator PK was 0.82 and the system PK was 0.98. System PK was less than 1 because in some scenarios there were so-called distracter tracks, the tracks that entered the zone of coverage, were engaged, but then turned and left the zone before they could be successfully killed.

Overall, PK was greater with the monochrome display, 0.83, than with the color display, 0.81, a small but statistically reliable difference. Interactions of other variables underlie this main effect: With the Mono-Color test order, PK improved only slightly over time, that is, from the first display type to the second. But with the Color-Mono test order, PK improved more substantially (see Table 4.1.2). With practice, then, PK improved, but the improvement was greater for those operators going from the color to the monochrome display than for those going from the monochrome to the color display. This is the test order effect: Operators who were tested first on the color display had to deal with both the simulation system and the color display. Their performance was worse in the beginning, but improved with practice to about the same level as the performance of operators tested in the Mono-Color order.

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[2] Data on the SPM's were lost for one operator for one scenario due to an error in the execution of the PAC.

Table 4.1.1. Mean number of tracks engaged for each scenario along with the minimum and maximum number of tracks engaged, according to track load.

	Scenario											
	1	2	3	4	5	6	7	8	9	10	11	12
Track Load	M	L	H	M	L	H	L	H	M	H	M	L
Mean	6.8	3.9	13.3	6.9	3.0	13.5	3.0	13.0	6.0	12.6	6.8	3.9
Min	6	3	11	6	3	11	3	12	5	11	4	3
Max	7	4	14	7	3	14	3	14	7	13	7	4

Note. L = low, M = moderate, H = high.

Table 4.1.2. Mean PK for the monochrome and color displays for the two test orders, Mono-Color and Color-Mono.

		Test Half	
		First	Second
Test Order	Mono-Color	0.81	0.85
	Color-Mono	0.78	0.86

Resource Conservation. Mean operator RC for the 12 scenarios was 77.73; system RC is, by definition, 100. RC was slightly greater for the monochrome display than for the color display (see Table 4.1.3). Again, as with PK, this is a small but reliable effect. Note that fewer missiles were launched with the color display than with the monochrome display but that more missiles were wasted which resulted in a lower RC score. The pattern of RC scores over time can be interpreted as a test order effect (see Table 4.1.4) although the effect was not statistically significant. Initially performance was slightly lower with the color display, but over time, performance was at the same level for both display types.

Table 4.1.3. The numbers of missiles launched and wasted and mean RC score according to display type.

		Missiles		RC
		Launched	Wasted	
Display	Monochrome	8.51	1.81	78.79
	Color	8.25	1.97	76.79

Table 4.1.4. Mean RC the monochrome and color displays for the two test orders, Mono-Color and Color-Mono.

		Test Half	
		First	Second
Test Order	Mono-Color	80.01	77.19
	Color-Mono	76.26	77.56

Table 4.1.5. Mean DOA for the monochrome and color displays for the two test orders, Mono-Color and Color-Mono.

		Test Half	
		First	Second
Test Order	Mono-Color	86.71	79.08
	Color-Mono	88.15	83.28

Defense of Assets. Mean operator DOA was 84.50 and system DOA was 100.00. Overall, there was no difference in DOA between scenarios seen on the monochrome display, 85.00, and those seen on the color display, 84.00. When the effect of test order is examined (see Table 4.1.5), DOA was actually slightly better with the color display than with the monochrome display during the first test half and worse during the second test half.

4.2 Task Performance Measures. The main finding with respect to the TPMs is that, overall, operator performance deviated substantially from system performance. On the one hand, operators engaged nearly 40% of the tracks early whereas the system engaged virtually no tracks early, early defined as before RT = 0. On the other hand, operators engaged the other 60% of the tracks later than the system by a factor of 40, with the result that less time was remaining in which to engage the tracks and the tracks were more threatening.

Further, there were no major performance differences as a function of display type. The color display neither helped nor hurt task performance as defined here. In two specific cases though--the percentage of early engagements and taking advantage of automatic hooking by acknowledging certain alerts--there is some evidence that the color display made performance more efficient.

Timeliness of Engagements. On average, the operators engaged tracks 27.37 seconds after RT = 0 whereas the system engaged tracks only 1.44 seconds after. The mean displayed value of TLL at engagement for the operators was 15.85, and for the

system it was 25.11. In other words, the operators engaged farther into the engagement window on average than did the system so that there was less time remaining before the last possible opportunity.

In order to more completely understand the time to engage in relation to RT = 0, it should be clear that both engagements occurring before RT = 0, and, therefore, having negative times, and those occurring after RT = 0 are included in the calculation of the overall time to engage. Breaking out those times separately (see Table 4.2.1), it becomes apparent that the time to engage was widely distributed, from an average of -20.64 seconds to +57.63 seconds. In fact, 39.24% of the engagements occurred before RT = 0. One consequence of early engagements was repeat engagements later in the engagement window when TLL was lower. Such was the case here where operators had an average of 1.79 repeat engagements per scenario.

The figures for times to engage and percent early engagements as a function of display type are shown in Table 4.2.2. The pattern reveals that mean times to engage before RT = 0 and after RT = 0 for the color display were closer to 0 than the times for the monochrome display. The percentage of early engagements was also smaller with the color display than with the monochrome display. Although none of these results were statistically significant, the pattern is intriguing. It appears that, with the color display, operators were more likely to wait for RT = 0 because it was highlighted in red. Mean TLL was not different as a function of display type, 15.77 for the monochrome display, and 15.93 for the color display.

Table 4.2.1. Mean time to engage in relation to RT = 0 and the percent of the early engagements for the operators and for the system.

	Time to Engage		Percent Early
	Before RT=0	After RT=0	
Operators	-20.64	57.63	39.24
System	-	1.44	0.00

Table 4.2.2. Mean time to engage in relation to RT = 0 and the percent of early engagements as a function of display type.

	Time to Engage		Percent Early
	Before RT=0	After RT=0	
Monochrome	-21.48	59.19	40.90
Color	-19.75	57.94	37.57

Activities Performed. The mean frequency of instances per scenario for each of the 17 activities is shown in Table 4.2.3. Due to the low frequency of many of the activities, only the five highest frequency activities will be reported further. Those five activities are alert acknowledge, engage data table, engage, hook, and monitor. Hook is the sum of the three different types of hooking, num hook, sequence hook and cursor hook.

The type of display alone made no significant difference for any of the five activities as measured by either the number of instances or the mean time per instance. The figures are listed in Table 4.2.4. Table 4.2.5 shows the same data broken out by both display and test order. For each of the activities, there were fewer instances during the second test half than during the first. For the alert acknowledge, engaged data table, engage, and hook activities, each instance of the activity took less time during the second half than during the first. However, for the monitoring activity, each instance took more time during the second half than during the first. In other words, there were fewer separate instances of monitoring, but each one lasted longer.

A closer examination of the number of instances of alert acknowledge and hook reveals an interesting relation between the two as a function of test order. Under the Mono-Color test order, there was a decrease of only 0.81 in the number of alert acknowledge instances, but a decrease of 2.03 in the number of

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Table 4.2.3. Mean number of instances per scenario for each of the 17 activities.

Activity or Switch-Indicator Press	Mean Number of Instances
Track Amp Table	0.77
Engaged Data Table	13.77
Other Tables	0.25
Track Data	1.30
Drop Track	0.00
Size or Offset	0.52
Engage	10.03
Hold Fire	0.00
Method of Fire	0.36
IFF	0.08
ID	0.00
Alert Acknowledge	12.36
Cursor Hook	0.60
Numeric Hook	2.64
Sequence Hook	7.60
Cancel Hook	0.55
Monitor	26.94

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hook instances. The pattern is exactly reversed under the Color-Mono test order: there was a decrease of 2.14 in the number of alert acknowledge instances, but a decrease of only 0.86 in the number of hook instances. Both of these interactions are highly significant. One possible explanation for these effects is that under the Mono-Color test order, with the experience gained by

Table 4.2.4. Mean number of instances and mean time per instance per scenario as a function of display type for the five primary activities.

	Instances		Time per Instance	
	Display		Display	
	Monochrome	Color	Monochrome	Color
Alert Acknowledge	11.92	12.59	2.50	2.52
Engaged Data Table	13.88	13.65	2.70	2.82
Engage	10.03	10.02	2.43	2.53
Hook	11.12	10.53	3.21	3.29
Monitor	26.89	26.98	10.66	10.97

Note. Mean time per instance is shown in seconds.

Table 4.2.5. Mean number of instances and mean time per instance per scenario as a function of display type and test order for the five primary activities.

		Instances		Time per Instance	
		Test Half		Test Half	
		First	Second	First	Second
Alert Acknowledge					
Test Order	Mono-Color	13.06	12.25	2.56	2.44
	Color-Mono	12.93	10.79	2.59	2.43
Engaged Data Table					
Test Order	Mono-Color	14.50	11.88	2.85	2.71
	Color-Mono	15.43	13.26	2.93	2.55
Engage					
Test Order	Mono-Color	10.26	9.61	2.56	2.49
	Color-Mono	10.43	9.81	2.57	2.31
Hook					
Test Order	Mono-Color	11.00	8.97	3.42	3.14
	Color-Mono	12.10	11.24	3.44	3.00
Monitor					
Test Order	Mono-Color	28.56	24.61	10.23	12.65
	Color-Mono	29.35	25.22	9.29	11.08

Note. Mean time per instance is shown in seconds.

the time the color display was used, the operators took advantage of the automatic hooking feature of acknowledging certain kinds of alerts thereby keeping the instances of alert acknowledge high while reducing the instances of hooking. In fact, in one scenario, one operator used only the automatic hooking feature. Under the Color-Mono test order, however, even with the experience gained over time, the operators did not take as much advantage of the automatic hooking when using the monochrome display. Thus, those operators kept the number of instances of hooking high while reducing the number of instances of alert acknowledge and, presumably, missing some alerts.

4.3 Subjective Workload Assessment. The higher the rating, the more difficult the scenario was determined to be. The track load variable is a check that subjective workload did vary significantly: workload ratings were 5.28 for low, 24.89 for moderate, and 40.79 for high track load scenarios. Although workload increased with increasing track load, even the high track load scenarios were rated below the middle of the scale.

Workload ratings for the scenarios presented with the monochrome display, 24.70, did not differ significantly from the ratings for the scenarios presented with the color display, 22.61. There was, however, an interaction of test order and display. These figures are shown in Table 4.3.1. It can be seen that only for the Mono-Color test order did workload ratings decrease over time. Thus, experience on the system and the color display combined to make the task seem easier to the operator. The combination of experience and the monochrome display did not make the task seem easier.

Further, workload ratings differed as a function of display, test order and track load. Under both test orders, workload

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Table 4.3.1. Mean SWAT workload ratings for the two test orders for the two display types.

		Test Half	
		First	Second
Test Order	Mono-Color		
Track Load	Low	9.58	4.28
	Moderate	22.50	20.53
	High	43.68	30.31
	All Track Loads	25.25	18.38
	Color-Mono		
Track Load	Low	5.15	2.11
	Moderate	26.45	30.10
	High	48.94	40.23
	All Track Loads	26.85	24.14

Note. The scale is from 0, low to 100, high.

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ratings decreased over time for low track loads. However, under the Color-Mono test order workload ratings actually increased for moderate track loads and decreased by about 8 points for high track loads; and under the Mono-Color test order, workload ratings stayed about the same for moderate track loads and decreased by more than 13 points for high track loads. Thus, the reduction of workload ratings seen as a result of the combination of experience on the system and the color display was even greater with increasing track load. This supports the notion that subjective advantages of the color display are greater the more cluttered the display.

Also of interest is the result that the officers rated the scenarios as more difficult than the enlisted operators, 29.00 compared to 18.31. This is probably due to the fact that the officers are only secondarily trained in the weapons controller task whereas the enlisted operators are primarily trained in the task.

4.4 Subjective Opinions. Previewing the results of the subjective opinion data discussed in this section: Overall, the ratings of eye and viewing comfort, image appearance and overall ease of viewing revealed no differences between the monochrome and the color displays although they do indicate some differences in what is distinctive or salient about them. Moreover, although the color display was preferred by only slightly more operators than the monochrome display, the comments of the operators preferring the monochrome display suggest that some specific aspects of the color display were preferable to the monochrome display.

Ratings of Eye Comfort, Viewing Comfort, Image Appearance and Overall Ease of Viewing. Mean ratings are shown in Table 4.4.1. A rating of 1 is low; a rating of 5 is high. Ratings for both displays were all higher than 3, that is, higher than the middle of the scale. Further, the ratings for the monochrome display and those for the color display were very close. The statistical analyses revealed no reliable differences as a function of display type on any of the scales.

The intercorrelations of the ratings did reveal some differences in how the operators considered the monochrome and color displays. The intercorrelation matrices for the ratings of the monochrome display and for the color display are shown in Appendix C. To summarize what the intercorrelations of the ratings indicate, the salient aspects of the monochrome display tended to be object specific (e.g., image distinctiveness and stability) whereas the salient aspects of the color display tended to be more global (e.g., ease of reading and color contrast). Further, although the same dimensions of eye comfort and image appearance were related to overall ease of viewing for both display types, the dimensions of vision comfort were also related to overall ease of viewing with the color display.

Table 4.4.1. Ratings for the two dimensions of eye comfort, two dimensions of vision comfort, five dimensions of image appearance, and overall ease of viewing for the two display types.

	Display	
	Monochrome	Color
Eye Comfort		
Tired/rested	3.50	3.79
Burning/normal	4.17	4.25
Vision Comfort		
Blurry/clear	4.42	4.21
Changing/consistent	4.33	4.21
Image Appearance		
Flickering/stable	4.04	3.96
Low/high contrast	3.50	3.58
Fuzzy/clear	4.33	4.33
Hard/easy to read	4.17	3.71
Confused/distinct	3.42	3.92
Overall Ease of Viewing		
Hard/easy to view	3.88	3.71

Note. The two words or phrases shown for each dimension are the endpoints of the rating scales.

Display Preference and Comments. The color display was preferred by only a slim margin, 13 to 11, over the monochrome display. Given the relatively small number of operators participating in the test, this cannot be called a decisive vote. The breakout according to officer and enlisted personnel is shown in Table 4.4.2. The officers slightly favored the monochrome display and the enlisted personnel favored the color display.

More instructive than the simple display preference are the operators' comments about why they preferred the display they did. A complete listing of all operator comments is contained in Appendix D. Only an overview will be presented here.

The operators who preferred the monochrome display said that it was easier to pick out specific targets or objects on the monochrome display than on the color display. They said that it was easier to distinguish the shape coding. Four of those operators mentioned that the color/brightness contrast was better, clearer with the monochrome display. Further, some said that the monochrome was 'easier on the eyes', that the color display had "too much action".

Virtually all of the operators who preferred the color display also commented that it was easier to pick out specific

Table 4.4.2. The numbers of officers and enlisted personnel preferring each type of display.

	Display	
	Monochrome	Color
Personnel		
Officers	7	5
Enlisted	4	8
Total	11	13

targets or objects, but for different reasons. Some said objects seemed more distinct and more separable. Others said color coded objects were easier to recognize and identify. One operator stated that the color display provided better coordination between the situation display and the tabular display.

Thus, both those preferring the monochrome display and those preferring the color display found reasons that the display of their preference made it easier to pick out specific targets or objects. There are some additional comments made by those preferring the monochrome display, however, that temper the strength of their preference and argue for some use of color. They said that, even though they preferred monochrome, color was beneficial for some things. Some of the comments were that color was good for the background volumes, for color coding the hostiles, for the Engaged Data Table, for high track loads, and for enhancing the contrast of the objects. One operator said that color was helpful although overused and another said that "maybe (color) just takes getting used to."

In addition to being asked to comment on why they preferred the display they did, the operators were asked, if colors were to be used, which colors they would keep the same and which ones they would change. Here the operators preferring monochrome and those preferring color generally made the same type of comments. The most frequent comment was that the number of different colors should be kept to a minimum. Some operators suggested using only colored outlines on the volumes rather than color-fill. Also, many commented on the difficulty they had reading the alphanumeric labels, that is, the target numbers and volume labels. The colors seemed to mix together making them hard to see. The masked terrain and range rings colors specifically needed to be made brighter or darker. Several of the operators thought that color could be used to advantage on the Alert Message Line and on other tables such as the Track Amp Table and some of the fault or status tables. Some operators suggested changing the friendly color from blue to green or white. All operators agreed that red was the best color for hostiles.

5.0 Conclusions and Recommendations.

5.1 Overall Level of Operator Performance. Operator performance was below or deviated from system performance on all measures even though the number of tracks was lower than that which actually could be expected in an air battle. Two reasons why this result might be an artifact of the experiment--the lack of recent operator training and the disparity between some aspects of the Color-PTOS and the tactical Patriot system--were mentioned in the beginning of the Results and Discussion section. A third possible reason for the difference between operator and system performance levels is not an artifact of the experiment. The reason is that, even at the track loads seen here, the display is cluttered, the operators are overloaded with information and, therefore, their performance is degraded. In the Introduction, this situation was identified as a driver of this research. Clearly, display clutter and information overload were correctly identified as problems.

5.2 Effects of Color on Summary Performance. As measured at the mission level, the color display, in the words of one of the test operators, "just takes getting used to." At first, the operators were 'thrown off' by the unfamiliar color display, but after just an hour of practice on the simulation system, their performance with the color display was at the same level as that with the monochrome display. What is not known from this study is whether further practice would have resulted in better performance with the color display compared to that with the monochrome one.

5.3 Effects of Color on Task Performance. As measured by the more specific TPMs, the color display did not help or hurt the timeliness of engagements, and it did not increase or decrease the number or duration of the various operator activities. In other words, the use of color did not produce a faster--or slower--operator. However, there is evidence that the use of color contributed to an operator's efficiency--the decrease in the percentage of early engagements and the taking advantage of the automatic hooking feature. Although it is not entirely clear how the "building blocks" of task performance combine to construct mission level performance, the importance of the specific tasks should not be underestimated. An increase in the efficiency of information processing at the task level could eventually translate into an improvement at the mission level, for example, after extended operations.

5.4 Effects of Color on Subjective Workload. As measured subjectively, the workload involved in performing the Weapons Controller task decreased over time with the color display but not with the monochrome display. Also, the reduction in workload was greater the heavier the track load. Note that practice alone did not make the task seem easier. It took the combination of

both practice and the color display to reduce the subjective assessment of workload.

5.5 Effects of Training. Underlying all the results is the constant factor of training or practice. The color display significantly impaired mission level performance until the operators were more practiced. Also, both the increased efficiency of information processing and the reduction of subjective workload were found only after sufficient practice. Perhaps the strongest conclusion to be drawn from these results, then, is that, with any major display modification, training and practice are critical.

5.6 Effects of Color on Subjective Ratings, Display Preference and Comments. Subjective measurement of eye and vision comfort, the appearance of the displayed image, and overall ease of viewing revealed that the test operators did not feel there were any differences between the two displays except in what was salient about the two displays. The individual object was more salient on the monochrome display and the general appearance of the display objects was more salient on the color display. And although the color display was favored by a slim margin over the monochrome display, stronger support for the use of color in the Patriot display comes from the operator comments. The thrust of the comments is that fewer colors should be used either because the current colors did not have sufficient contrast or because they were used to code too many different levels of information. In other words, there were both perceptual problems and problems with the ways in which color was used, that is, the coding, decluttering and highlighting. Both problems can be addressed by reducing the number of colors.

5.7 Recommendations. The most specific recommendation to come out of this study is that, if color is to be used in the Patriot display, use even fewer colors. Using fewer colors will make it simpler to ensure sufficient color contrast and, at the same time, restrict the number of ways in which color can be used. A final recommendation on the number and combination of colors would, ideally, involve prioritizing all of the possible uses of color and asking Patriot operators and subject matter experts to comment on various implementations. For example, the use of different colors for different volume types could turn out to be a low priority. If all volumes were the same color, individual volumes would retain the distinct, unified appearance seen here, but multiple color coding levels would not be used. Color codes per se could be reserved for the tracks, friendly - blue, unknown - yellow and hostile - red. Alternatively, the background volumes could be color coded and only specific tracks would then be highlighted--the most threatening tracks, the track at the top of the TBEQ, the track being referenced by the Alert Message Line, or the hooked track. Also, the solid color-fill for the search and track sectors could be eliminated which would

reduce the number of background colors against which objects had to be contrasted. Further, the alphanumeric labels could be all in white for maximum visibility. Color highlighting could also be used on all the main tables, but limited to a single alerting color rather than multiple colors.

Finally, the more general recommendation to come out of this study has to do with reconciling the meager performance enhancements obtained with the color display with the striking, obvious differences in appearance between the monochrome and the color displays. A key distinction to be made is the difference between what the viewer sees and what the user sees. The viewer sees the display in it overall configuration, whereas the user, being oriented to the task, sees the specific display details. Thus, this particular color display reduced the overall sense of workload, but it did not enhance performance. The two questions remaining are (1) whether the reduced workload brought about by the overall use of color will eventually translate into enhanced performance at higher track loads or after extended operations, and (2) whether color can be used to enhance performance as it depends on specific display details.

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APPENDIX A
SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE (SWAT) MATERIALS AND EXAMPLES

Figure A.1. An example of one of the 27 SWAT sorting cards showing Time Load level 1, Mental Effort Load level 3, and Psychological Stress Load level 2.

TIME LOAD - Often have spare time. Interruption or overlap among activities occur infrequently or not at all.

MENTAL EFFORT LOAD - Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS LOAD - Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.

Table A.1. The SWAT scale obtained for the test operators in this experiment.

----Dimensions of Workload----			
Time	Mental Effort	Psychological Stress	Scale Values
----------Levels----------			
1	1	1	0.0
1	1	2	18.9
1	1	3	38.4
1	2	1	12.9
1	2	2	31.7
1	2	3	51.2
1	3	1	26.7
1	3	2	45.6
1	3	3	65.1
2	1	1	15.4
2	1	2	34.3
2	1	3	53.8
2	2	1	28.3
2	2	2	47.1
2	2	3	66.6
2	3	1	42.1
2	3	2	61.0
2	3	3	80.5
3	1	1	34.9
3	1	2	53.8
3	1	3	73.3
3	2	1	47.8
3	2	2	66.6
3	2	3	86.1
3	3	1	61.6
3	3	2	80.5
3	3	3	100.0

Note. A score of 0 represents low workload and 100 represents high workload. The ratings on the three dimensions of workload are translated to a single score using this scale. For example, if an individual rated a task 1, 3, and 2 on the three dimensions, that translated to a single score of 45.6.

Figure A.2. The instructions and the SWAT rating scales used for rating individual scenarios.

Please rate the scenario you just completed on each of the three dimensions of workload. Circle the appropriate number.

Time Load

1	2	3
Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.	Occasionally have spare time. Interruptions or overlap among activities are very frequent.	Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

Mental Effort Load

1	2	3
Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.	Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.	Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

Psychological Stress Load

1	2	3
Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.	Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.	High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

APPENDIX B
SUBJECTIVE OPINION RATING MATERIALS

Figure B.1. The rating scales used for the subjective ratings of the two dimensions of eye comfort, the two dimensions of viewing comfort, the five dimensions of image appearance, and overall viewability.

You have now completed six scenarios, all with the monochrome (color) display. Think back over all six of the scenarios as you make the following ratings. Circle the appropriate number

Use these two rating scales to describe how your eyes felt while you worked on the six scenarios. Circle the appropriate number.

1 2 3 4 5
tired rested

1 2 3 4 5
burning normal

Use these two rating scales to describe your vision (how well you were seeing) while you worked on the six scenarios.

1 2 3 4 5
blurry clear

1 2 3 4 5
changing consistent

Use these five rating scales to describe the appearance of the display objects in the six scenarios.

1 2 3 4 5
flickering stable

1 2 3 4 5
low color/brightness contrast high color/brightness contrast

1 2 3 4 5
fuzzy clear

1 2 3 4 5
hard to read/ illegible easy to read/ legible

1 2 3 4 5
confused with other objects separate & distinct from other objects

Overall, how easy was this display to view? In other words, rate this display on ease-of-viewing.

1 2 3 4 5
hard to view easy to view

APPENDIX C
INTERCORRELATION MATRICES OF THE RATINGS OF EYE COMFORT, VIEWING COMFORT, IMAGE APPEARANCE, AND OVERALL EASE OF VIEWING FOR THE MONOCHROME AND COLOR DISPLAYS

Table C.1. Correlation matrix for the ratings of the monochrome display on the dimensions of eye comfort, vision comfort, image apperance and of overall ease of viewing. Correlations marked with an asterisk are significant at $p < .05$. EC = eye comfort, VC = vision comfort, IAP = image appearance, and EOV = ease of viewing. The words under the variable labels are the endpoints of the rating scales.

	EC1	EC2	VC1	VC2	IAP1	IAP2	IAP3	IAP4	IAP5	EOV
EC1 tired/rested	1.00	0.62*	0.62*	0.52*	0.32	0.27	0.56*	0.24	0.30	0.41*
EC2 burning/normal		1.00	0.72*	0.57*	0.19	0.23	0.48*	0.39	0.43*	0.42*
VC1 blurry/clear			1.00	0.61*	0.46*	0.33	0.49*	0.25	0.31	0.22
VC2 changing/consistent				1.00	0.21	0.05	0.11	0.26	0.33	0.32
IAP1 flickering/stable					1.00	0.37	0.29	0.20	0.15	-0.04
IAP2 low/high contrast						1.00	0.22	0.14	0.15	0.33
IAP3 fuzzy/clear							1.00	0.43*	0.27	0.48*
IAP4 hard/easy to read								1.00	0.78*	0.50*
IAP5 confused/distinct									1.00	0.56*
EOV hard/easy to view										1.00

Table C.2. Correlation matrix for the ratings of the color display on the dimensions of eye comfort, vision comfort, image appearance and of overall ease of viewing. Correlations marked with an asterisk are significant at $p < .05$. EC = eye comfort, VC = vision comfort, IAP = image appearance, and EOV = ease of viewing. The words under the variable labels are the endpoints of the rating scales.

	EC1	EC2	VC1	VC2	IAP1	IAP2	IAP3	IAP4	IAP5	EOV
EC1 tired/rested	1.00	0.71*	0.61*	0.66*	0.17	0.10	0.42*	0.47*	0.02	0.60*
EC2 burning/normal		1.00	0.64*	0.53*	0.20	0.14	0.65*	0.52*	0.02	0.62*
VC1 blurry/clear			1.00	0.72*	0.36	0.34	0.56*	0.34	0.14	0.52*
VC2 changing/consistent				1.00	0.32	0.17	0.38	0.23	0.34	0.57*
IAP1 flickering/stable					1.00	0.22	0.06	-0.08	0.34	0.12
IAP2 low/high contrast						1.00	0.50*	0.26	0.25	0.23
IAP3 fuzzy/clear							1.00	0.68*	0.16	0.66*
IAP4 hard/easy to read								1.00	0.33	0.79*
IAP5 confused/distinct									1.00	0.54*
EOV hard/easy to view										1.00

APPENDIX D
OPERATOR COMMENTS

The test operators made comments in response to the following questions. (Comments of pilot test operators are also included here.)

1. You have now completed all 12 scenarios. The first six were with the monochrome (color) display; the second six were with the color (monochrome) display. Thinking back about both displays, overall, which display did you prefer?

2. Please give the reasons why you preferred the display you did.

3. If the Patriot weapon system were to have a color display like the one you saw here today, what changes would you make, if any? For example, would you change the colors? Would you use the colors differently? Would you add color to any other part of the display?

4. Would you change the color used for these specific display objects? If so, how? (Followed by a list of display objects.)

PILOT OPERATOR #1
RANK: 1LT
MOS: 14E
PREFERENCE: COLOR
REASONS: The different colors provided an easier identification of areas/targets. Although the symbology of enemy/friends are distinct the color made it more apparant of who was where. I feel the colors are softer on the eyes than the monochrome was. Color makes the scenario seem more like a game versus monochrome, it is still more pleasant to look at. I had no trouble identifying the symbology. The change to color is a matter of getting accustomed to - great work.
CHANGES: I feel the colors selected worked fine, I do recommend keeping it to a minimum.
SPECIFIC CHANGES:
MASKED TERRAIN: Could be made a little more intense in color.

PILOT OPERATOR #2
RANK: 2LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: I prefer the monochrome because it was not as bright as the color. The color screen was easier to read, but it was very tiring because the colors used were too bright and forceful--you should use dull colors.
CHANGES: Yes, I would change the colors and like I said I would change them to dull colors-more green-I would also make the Prohibited and Restricted areas different colors. All the numbers labeling the areas should be black because with the colors used now they tend to inter-mix making them impossible to read.
SPECIFIC CHANGES:
MASKED TERRAIN: Black
WEAPONS CONTROL VOLUME-HOLD: Light gray
WEAPONS CONTROL VOLUME-FREE: Medium gray
WEAPONS CONTROL VOLUME-TIGHT: Dark gray
RESTRICTED VOLUME: Light brown
PROHIBITED VOLUME: Dark brown

PILOT OPERATOR #3
RANK: 1LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: The color display tended to make up a 3 dimensional type atmosphere, which I was not used to working with. The monochrome always appeared flat, like a radar screen. The only advantage I see to color is the contrast ability, but I don't have any problem knowing what the (areas, volumes, etc.) feature I'm looking at is anyway. I definitely like using monochrome because it feels more like what it ie, a radar screen.
CHANGES: I would not switch, but if I did, I would use as few different colors as possible, and make them contrast as much as possible. Stay away from the 3-D effect. As for colors used here in this test, there were too many different ones without enough contrast.

PILOT OPERATOR #5
RANK: 2LT
MOS: 14E
PREFERENCE: COLOR
REASONS: I preferred the color display. The reasons are that things were much more distinguishable. I could tell exactly what each TGT was and where it was. The corridors and other display stood out very well, it was easy to see and read. I did not have to strain. It was not a strain on my eyes. A few colors could be changed but it was very good, especially the Data Tabs.
CHANGES: I would change the color of the volumes because they look too dull. The Free volumes could be red as are the hostiles because this notes danger. The Hold & Tight could be blue for possible friendly or targets not to be fired on. The Sector could be darker gray to bring out the other colors. If the display is a little darker it is not such a strain. The Prohibited and Restricted could also be a red for danger, maybe a darker red. I liked the Tabs black.
SPECIFIC CHANGES:
FEBA: Change to black as it's better visible.
SEARCH SECTOR: Make it darker
TRACK SECTOR: Darker
RANGE RINGS: Change to black. They show up better
WEAPONS CONTROL VOLUME-HOLD: Blue
WEAPONS CONTROL VOLUME-FREE: Red
WEAPONS CONTROL VOLUME-TIGHT: Blue
RESTRICTED VOLUME: Red
PROHIBITED VOLUME: Red

PILOT OPERATOR #6
RANK: SSG
MOS: 24T
PREFERENCE: COLOR
REASONS: Several instances it was much easier to see the targets due to their color designator. Video display was sharp and clear. Had no problems with the color display. Much Preferred.
CHANGES: At this time I would not change any colors.
SPECIFIC CHANGES:
ALERT MESSAGE LINE: Change the alert line color to RED

OPERATOR #1
RANK: SSG
MOS: 24T
PREFERENCE: MONOCHROME
REASONS: I prefer monochrome because (1) contrast of targets and background was better (2) less eye strain.
CHANGES: I would delete sector coverage color or change it in a way that all TGT's will stand out better. I would change the color of the alerts (they do not stand out). It may cause less eye strain if only the outline of each shape was in color. Instead of the information in "ENG TAB" turning red when "RT" reaches 0. RT should turn red when "TLL" reaches 10 or less.
SPECIFIC CHANGES:
SEARCH SECTOR: No color
TRACK SECTOR: No color
ALERT MESSAGE LINE: Red or any color that will stand out better in white.

OPERATOR #2
RANK: SSG
MOS: 24T
PREFERENCE: MONOCHROME
REASONS: I don't really care for the full color picture. I prefer the lines colored as a reference or guide. I prefer the monochrome also because I like as little brightness as possible from the scope because it is easier on the eyes. The engage data is also easier to read, but I would like to see targets that have zero RT in a different color.
CHANGES: I would use colored outlines and I would add some colors for the different sector bounds. Staying with the idea of only coloring the outlines. I also like a dark background behind everything.
SPECIFIC CHANGES:
BACKGROUND: Black
ENGAGED DATA TAB: I like the color change

OPERATOR #3
RANK: 1LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: I liked the dark and light contrast. It was easier to concentrate on the targets in monochrome because they were a little brighter. However, the monochrome does have its drawbacks: (1) Prohibited & Restricted areas were easy to ignore. (2) When there were a lot of tracks it was more confusing than the color display. Monochrome is harder on the eyes. I would like to suggest another alternative. I think if the background was black like the monochrome, but the outlines done in different colors, then you would have an optimal system.
CHANGES: I think there should be a combination of the two displays. You should keep the dark background of the monochrome but have different colored outlines. Free, Hold and Tight areas should be in different colors. Prohibited and Restricted areas should be outlined in different colors. Range Rings should be different because they are very hard to see, Masked Terrain is hard to see too.
SPECIFIC CHANGES:
SEARCH SECTOR: Gray
TRACK SECTOR: Black
MASKED TERRAIN: White-dashed line. * If you change the Search & Track sectors, then leave this alone.
WEAPONS CONTROL VOLUME-HOLD: Dark orange solid outline
WEAPONS CONTROL VOLUME-FREE: Yellow solid outline
WEAPONS CONTROL VOLUME-TIGHT: Light orange solid outline
RESTRICTED VOLUME: Pink outline-dashed
PROHIBITED VOLUME: Red outline-dashed
DEFENDED AREA/POINTS: Solid
SAFE PASSAGE CORRIDOR: Outline only
BACKGROUNG: Black
ENGAGED DATA TAB-PARTICULARLY THE COLOR WHEN RT GOES TO 0: Stay red; tab should be reversed.
OTHER TABS: Track AMP data-RT should turn red when it goes to zero.
ALERT MESSAGE LINE: Light gray or black

SPECIFIC CHANGES:

FRIENDLY TRACKS: Green
UNKNOWN TRACKS: Yellow
HOSTILE TRACKS: Red
LNIPS, PIPS, TRAILS: White
MISSILES: Red
FEBA: Blue-separate with dotted lines
SEARCH SECTOR: Blue-separate with dotted lines
TRACK SECTOR: Blue-separate with dotted lines
RANGE RINGS: Leave off-black dotted line
MASKED TERRAIN: Leave off-black dotted line
GENERAL POINTS: Green
CRG: Green
BATTALION FLAG: Green
CURSOR: White
NORTH SYMBOL: White
WEAPONS CONTROL VOLUME-HOLD: Green
WEAPONS CONTROL VOLUME-FREE: Red
WEAPONS CONTROL VOLUME-TIGHT: Yellow
RESTRICTED VOLUME: White-all dotted lines
PROHIBITED VOLUME: White-all dotted lines
DEFENDED AREA/POINTS: White-all dotted lines
SAFE PASSAGE CORRIDOR: White-all dotted lines
BACKGROUND: Blue
ENGAGED DATA TAB: ? Not in color gray
OTHER TABS: ? Not in color gray
ALERT MESSAGE LINE: ? Not in color gray

PILOT OPERATOR #4
RANK: 2LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: The reason I chose monochrome is because to me it seemed clearer and more distinct. The different shades in the monochrome allows the operator to distinguish one object from the other. Also it keeps the system simpler.
CHANGES: Yes, I would change some of the colors because they seemed to be too similar which made reading or distinguishing them difficult at times. Please see the following sheets for how I would use the colors differently, and no, I would not add any more colors to the screen.
SPECIFIC CHANGES:

FRIENDLY TRACKS: Yes, this should be green.
UNKNOWN TRACKS: Yes, this should be blue.
RANGE RINGS: Yes, these colors seemed to meld into the background color. They ought to be darker.
RESTRICTED VOLUME: Yes, I could not see this color behind the color for Weapon Control Volumes.
BACKGROUND: Yes, the present color allows too many other colors to meld with it.
ENGAGED DATA TAB: Yes, the white TAB background was too bright.

OPERATOR #4
RANK: 2LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: Monochrome was much easier to read. The color display was just too much action for the eyes. I could rarely read the track numbers in the color display. When a red (enemy) target entered an orange (weapon control) it was bothersome and difficult to read. The inside of an ECS is very dark and black on white scenarios are better. I hope they stay with monochrome. Color is terrible, confusing and reminds me of an arcade game.
CHANGES: Because I am opposed the only color change I could recommend would be brighter track numbers. Harder colored reds and blues!! Also the unknown yellow will sometimes mesh into a blue Friendly and be very difficult to distinguish. The safe passage corridors are a good color but the Restricted Volumes and Prohibited Volumes should be a bit brighter...stay with monochrome.
SPECIFIC CHANGES:
FRIENDLY TRACKS: A bit darker would be nice
UNKNOWN TRACKS: Perhaps green, yellow is very irritating and hard to see.
HOSTILE TRACKS: Must stay red!!!
FEBA: Not really noticeable, don't really refer to it much.
TRACK SECTOR: No problem, could be a bit brighter line. I sometimes forgot it was there.
RANGE RINGS: Rarely use this anyway in the ECS, makes for too much clutter.
GENERAL POINTS: Good, not used much but easy to find and reference
CRG: Green really stands out. Good color.
BATTALION FLAG: Green is good, easy to distinguish.
RESTRICTED VOLUME: Pinkish or orangish. Color is too light and irritating.
PROHIBITED VOLUME: Same as above, difficult to read track numbers at times.
DEFENDED AREA/POINTS: Easy to see boxes, sometimes defended points seem too small.
SAFE PASSAGE CORRIDOR: Blue is excellent color.
BACKGROUND: Good in both monochrome and color. Prefer darkest background possible.
ENGAGED DATA TAB: Liked how it turned to red when RT reached 0, very noticeable.
ALERT MESSAGE LINE: A bit annoying when I kept getting alerts on already engaged targets but the lines themselves were no problem to read.

OPERATOR #5
RANK: 2LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: With monochrome there were less distractions to filter through than with color. The blinking and varying brightness were enough to distinguish tracks from each other when needed. The color was helpful but was overused and would be much more useful in limited situations.

CHANGES: Don't make everything different colors. The colors don't make things stand-out if everything has its own color. If only some things such as engagable tracks and tracks with alerts on them were colored different, it would make them stand out immensely and be a big help to the operator. Use color around outside of volumes, corridors, etc., rather than filling in solids.

SPECIFIC CHANGES:

HOSTILE TRACKS: Red is Great!

TRACK SECTOR: Shading makes search sector 3-D instead of setting off track sector for search.

RANGE RINGS: Change to some distinct color. They are hard to see as are.

DEFENDED AREA/POINTS: Change to STAND-OUT more

ENGAGED DATA TAB-PARTICULARLY THE COLOR WHEN RT GOES TO 0: Very helpful as is setting off lines with red.

OPERATOR #6
RANK: 2LT
MOS: 14E
PREFERENCE: MONOCHROME

REASONS: The monochrome display was more conducive to picking out particular (target) display than the color. When going from the TBE tab to the display my eyes would require a great deal of scanning to discern the object in question. In all the relative lack of color in the monochrome display proved easier to work with.

CHANGES: Color, for colors sake, fails to accomplish the objective of making certain important objects stand out. I think that reducing the number of objects with color to just those with a high priority would be more effective. (Example, get rid of color in the Search and Track sector). If everything has a different color they all tend to blend and nothing jumps out. If just priority or hostile targets were a different color I believe the operator would benefit.

SPECIFIC CHANGES:

FRIENDLY TRACKS: Normal green

UNKNOWN TRACKS: Normal green

HOSTILE TRACKS: Red

TRACK MODIFIERS: Normal green

LNIPS, PIPS, TRAILS: Normal green

MISSILES: Normal green

FEBA: Normal green

SEARCH SECTOR: Normal green

TRACK SECTOR: Normal green

RANGE RINGS: Normal green

MASKED TERRAIN: Some stand-out color

GENERAL POINTS: Some stand-out color

CRG: Some stand-out color

BATTALION FLAG: Some stand-out color

CURSOR: Some stand-out color

NORTH SYMBOL: Some stand-out color

WEAPONS CONTROL VOLUME-HOLD: Stand-out color

WEAPONS CONTROL VOLUME-FREE: Stand-out color

WEAPONS CONTROL VOLUME-TIGHT: Stand-out color

RESTRICTED VOLUME: Stand-out

PROHIBITED VOLUME: Stand-out

DEFENDED AREA/POINTS: Normal color

SAFE PASSAGE CORRIDOR: Normal color
BACKGROUND: Normal color
ENGAGED DATA TAB: Normal color
OTHER TABS: Normal color
ALERT MESSAGE LINE: Normal color

OPERATOR #7
RANK: SP4
MOS: 24T
PREFERENCE: COLOR
REASONS: Because it made it easier for me to identify targets easier and track numbers.
CHANGES: I would change the color of the Restricted or Prohibited Volume because they are too close together in color and makes it very difficult to tell the difference.
SPECIFIC CHANGES:
RESTRICTED VOLUME: To a darker or lighter color
PROHIBITED VOLUME: To the opposite of Restricted Volume
ENGAGED DATA TAB-PARTICULARLY THE COLOR WHEN RT GOES TO: Liked that

OPERATOR #8
RANK: PFC
MOS: 24T
PREFERENCE: COLOR
REASONS: My reasons for picking color were as follows: I like that it is made easier to identify tracks, and other points on the screen: to sum it up I feel the color screen can help an operator find things with less workloads.
CHANGES: The colors that I had seen does not require any improvement, one exception: (Alert Message Line)
SPECIFIC CHANGES:
OTHER TABS: These could have entries added to them depending on urgency of items on these tabs.
ALERT MESSAGE LINE: Could use a more active color, the one being used was too passive.

OPERATOR #9
RANK: PFC
MOS: 24T
PREFERENCE: COLOR
REASONS: Clearer more distinct, easy to separate one object from another, color showed priority on important objects.
CHANGES: Range rings-bright yellow.
SPECIFIC CHANGES:
RANGE RINGS: Yellow

OPERATOR #10
RANK: SP4
MOS: 24T
PREFERENCE: COLOR
REASONS: I liked the color differentiation. It allowed me to keep my mind on other details rather than looking at and reaffirming the same things over and over because I forgot (mainly I.D. areas). Also, it was easy on the eyes as far as contrast and brightness while, at the

same time remaining very much legible. The color display also allowed for better coordination and use of Tabular display information and, also too, symbol modifiers were very sharp. I believe I could use this system to advantages such as better coverage with same equipment and also, operate for longer time period since my eyes don't get strained as much.

CHANGES: No. For the most part, the colors used where used good. I feel masked areas could have been a little higher in contrast due to their extreme importance. I wouldn't mind seeing the alert line in a bright shade of a high contrast color or maybe just certain alerts come up in color (such as Pri Eng) in bright-bright red, while alerts such as LS LOW MSL could remain black.

SPECIFICE CHANGES:

MASKED TERRAIN: Now orange-would change to a brighter shade or to green.

OTHER TABS: Maybe label one color, data another.

OPERATOR #11
RANK: 1LT
MOS: 14E
PREFERENCE: COLOR

REASONS: The color contrast made it easier to read. It helps the operator to make decisions faster.

CHANGES: I would change the blinking missile intercept line.

SPECIFIC CHANGES: None

OTHER TABS: Maybe Fault Data in red to catch the eye.

OPERATOR #12
RANK: 1LT
MOS: 14E
PREFERENCE: COLOR

REASONS: (1) Easy to distinguish hostile, unknown and friendly tracks (from one another). (2) Eye strain did not seem to be as evident. (3) When release time reached zero, on a specific track, TBE data changed to red. (4) The "X" that appeared in the Track, which was being referenced by an alert. (5) Readability of character.

CHANGES: Range Rings - use a color which is easier to detect.

SPECIFIC CHANGES:

Purple is hard to see, without straining (change to something brighter).

OPERATOR #13
RANK: CPT
MOS: 14E
PREFERENCE: COLOR

REASONS: The color display made a quick distinction between volumes. It was much easier to determine what was what. This took quite a mental workload off me.

CHANGES: NO, the colors were quite good. There were none so bright/sharp that it distracted me, but still allowed for easy distinction between volumes. I would not use colors differently, nor would I add color to any other part.

SPECIFIC CHANGES:

MISSILES: Maybe change to white

CURSOR: Not so "bright" a white. It often distracted me so I would move it off to one side.

WEAPONS CONTROL VOLUME-FREE: Maybe a red
ENGAGED DATA TAB: No the lines going to red when RT = 0 was super! It was another change to alert the operator and make his job easier.

OPERATOR #14
RANK: SSG
MOS: 24T
PREFERENCE: COLOR
REASONS: It's alot easier to recognize objects on the scope and alot easier on the eyes.
CHANGES: I believe that the colors are very nice although the "pink" for restircted areas seems a bit too bright.
SPECIFIC CHANGES:
RANGE RINGS: Yes, make them a bit brighter.

OPERATOR #15
RANK: SFC
MOS: 24T
PREFERENCE: COLOR
REASONS: The difference in the color contrast will help the operator to distinguish the different targets. An operator who is at the console at a long period of time will be able to operate with less problems.
CHANGES: None
SPECIFIC CHANGES: None
OTHER TABS: Maybe color could be used on Track Amp Tab.

OPERATOR #16
RANK: 1LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: I preferred the monochrome display because it is a little less confusing. The overlapping of color made it hard to see certain areas of concern where the monocolor screen had less color that could confuse me. It might just take a little getting used to, but today I was more comfortable with the monochrome screen.
CHANGES: I would suggest using less color than the color CRT had today. I felt it was interesting, but too colorful. I think the use of color on the Patriot CRT is a good idea, but not everything has to have a color. I would probably like just an outlined area with different colors than an entire section. I think staying with the mono (green) screen and adding just a few colors to emphasize important points may be more efficient.
SPECIFIC CHANGES:
FRIENDLY TRACKS: White
HOSTILE TRACKS: Red
ENGAGED DATA TAB: I sometimes used it to decide to engage when it automatically went red.

OPERATOR #17
RANK: SFC
MOS: 24T
PREFERENCE: COLOR
REASONS: The color was easier to use do to the fact I was able to distinguish different objects easier.

CHANGES: I would have to change some of the colors.
SPECIFIC CHANGES:
FRIENDLY TRACKS: Green
UNKNOWN TRACKS: Yellow
HOSTILE TRACKS: Red
TRACK MODIFIERS: Same as Track
LNIPS, PIPS, TRAILS: Same as Track
MISSILES: White
FEBA: White
ENGAGED DATA TAB: Should go yellow when RT is down to 10 and red when TLL is down to 10.
OTHER TABS: FP Status, Nogo=Red, Degraded=Yellow. Also Operator Access and Missile Inventory Track Amp, Green/Red, Garbled=Yellow.

OPERATOR #18
RANK: SP4
MOS: 24T
PREFERENCE: COLOR
REASONS: It is easier to look at and once you got to know what color represents what it is quicker and easier to find what you are looking for. If its not harder to troubleshoot and fix than the green display I think its all right.
CHANGES: Some of the colors kind of mixed together when I looked at them. Some of the letters got covered up by other things. Like the range rings and masked terrain dotted lines were hard for me to see.
SPECIFIC CHANGES:
FEBA: Darker lines
RANGE RINGS: Make longer dashes or darker
MASKED TERRAIN: Make longer dashes or darker
WEAPONS CONTROL VOLUME-HOLD, WEAPONS CONTROL VOLUME-FREE, WEAPONS CONTROL VOLUME-TIGHT: IT's good they are all the same color.
RESTRICTED VOLUME, PROHIBITED VOLUME: I think these should have their own colors.

OPERATOR #19
RANK: 1LT
MOS: 14E
PREFERENCE: COLOR
REASONS: Color made it easier to differentiate between the symbology. White background on Tabular Display area made it easier to read and helped the alert line stick out. Overall the color display made the console less monotonous and easier to read. Didn't care for the aspect that the color screen doesn't update all Tracks and Data simultaneously though.
CHANGES: None, except Alert Line and Track when Alerted or hooked.
SPECIFIC CHANGES:
ALERT MESSAGE LINE: Maybe a different color than the rest of the Tabular Display.

OPERATOR #20
RANK: CPL
MOS: 24T
PREFERENCE: MONOCHROME

REASONS: The monochrome display is very simple to view and interpret. There are no colors to conflict (i.e., The prohibited and restricted volumes and the weapon control volumes. The pink and orange just cancel each other out). The monochrome is easier on the eyes.
CHANGES: I wouldn't worry about changing a thing because if the display went to color like I saw today, I would walk out of the MOS.
SPECIFIC CHANGES: None

OPERATOR #21
RANK: 1LT
MOS: 14E
PREFERENCE: COLOR
REASONS: The color display gives the operator a better perspective of the Air Battle. Helps to reduce eye fatigue. Since symbology is color coded, adding to effectiveness of the display.
CHANGES: Overall, it should not be changed.
SPECIFIC CHANGES:
RANGE RINGS: Hard to see at times. Perhaps a darker color.
NORTH SYMBOL: Enlarge the North Arrow.

OPERATOR #22
RANK: CPL
MOS: 24T
PREFERENCE: MONOCHROME
REASONS: I preferred the monochrome Display
a. Objects are clearer and easier to see
b. Targets are more distinct
c. I found the color display to be distracting with all the different colors, although the soft pastel colors were easy on the eyes.
d. The monochrome display is probably a great deal less expensive.
CHANGES: If I had to choose color I would prefer a pale blue background with all volumes, assets, defended areas etc. outlined in yellow and all targets red. The red target was the easiest to see.
SPECIFIC CHANGES:
FRIENDLY TRACKS: Red
UNKNOWN TRACKS: Red
HOSTILE TRACKS: Red
TRACK MODIFIERS: Red
LNIPS, PIPS, TRAILS: Red
MISSILES: Red
FEBA: Yellow
SEARCH SECTOR: Darker blue
TRACK SECTOR: Pale blue
RANGE RINGS: Yellow
MASKED TERRAIN: Yellow
GENERAL POINTS: Yellow
CURSOR: Yellow
WEAPONS CONTROL VOLUME-HOLD: Yellow
WEAPONS CONTROL VOLUME-FREE: Yellow
WEAPONS CONTROL VOLUME-TIGHT: Yellow
RESTRICTED VOLUME: Yellow
PROHIBITED VOLUME: Yellow
DEFENDED AREA/POINTS: Yellow
SAFE PASSAGE CORRIDOR: Yellow
BACKGROUND: Black
ENGAGED DATA TAB: White with black lettering at all times.

OPERATOR #23
RANK: 2LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: It was easier to pickout separate targets. I was used to seeing display this way. I did not have to recognize a color code as well as a shape code.
CHANGES: I would use only outlined colors for the background, and the thing we need to see at a scan, in solid shades of color. WCV-outline, ID volumes, assets, tracks-solid.
SPECIFIC CHANGES: None
OTHER TABS: Red for Negative IFF return - or ID change from U to H. First, they are very hard to see at a glance. If the rest of the display was not blinking, maybe my eyes could find the faster blink easier. Second, the X and O symbol did not add or subtract from display. It is the blinking that was of note.

OPERATOR #24
RANK: 2LT
MOS: 14E
PREFERENCE: MONOCHROME
REASONS: The colors used (pastels) I did not like. The color used for the Sector was not good, I think it should have been a darker color therefore the Range Rings, defended areas etc. would have shown-up better. The colors used were too soft, it seems to me when people are dealing with a combat situation it helps to have some dark colors - however, the red for hostiles was effective. The monochrome display I liked better because there were not alot of colors to distinguish from only shapes-this seems easier for me.
CHANGES: Yes, I would change the color-mentioned on previous page.
SPECIFIC CHANGES:
FRIENDLY TRACKS: Darker color
LNIPS, PIPS, TRAILS: Same
MISSILES: Same
FEBA: Darker - maroon
SEARCH SECTOR: Darker - green
TRACK SECTOR: Darker
RANGE RINGS: Darker - navy possibly
MASKED TERRAIN: Light color
CRG: Same
BATTALION FLAG: Same
CURSOR: Same - keep lighter color
NORTH SYMBOL: Same
WEAPONS CONTROL VOLUME-HOLD: Darker color
WEAPONS CONTROL VOLUME-FREE: Darker color
WEAPONS CONTROL VOLUME-TIGHT: Darker color
RESTRICTED VOLUME: Darker color
PROHIBITED VOLUME: Darker
DEFENDED AREA/POINTS: Darker
SAFE PASSAGE CORRIDOR: Same
BACKGROUND: Definitely a darker background, possibly black
OTHER TABS: Color could be used for TLL/RT.